APPENDIX E

UPDATING THE FIRST PROSPECTIVE STUDY'S TITLE VI ANALYSIS

This appendix presents a revised approach for a benefit/cost analysis of the Clean Air Act's Title VI (regulation of ozone depleting substances). Updating the first prospective study's analysis of Title VI costs and benefits is necessary for several reasons.

First, a few new ozone-depleting substances (ODS) regulations are now in place – or are expected to be promulgated – that will impose costs on and offer benefits to U.S. citizens. The 812 control scenario will be updated to incorporate these new regulations.

Second, the first prospective study relied extensively on regulatory impact analysis (RIA) estimates of benefits and costs prepared at various times in the past for specific stratospheric ozone protection regulations. Much has changed since the preparation of the background RIAs used in the 812 study regarding ozone depletion science, the response of health effects due to ultraviolet (UV) exposure, and many other factors central to estimating the benefits of addressing ozone depletion and recovery. In response to these changes, EPA has updated input data, such as population projections and ODS emissions, and has incorporated several advancements into its model of ozone depletion and health impacts, including improvements in the following areas:

- measurement of stratospheric ozone concentrations;
- forecasts of the impact of emissions of certain ODS on stratospheric ozone concentrations;
- predictions of the impact of changing ozone concentrations on ultraviolet (UV) radiation intensity at the earth's surface; and
- the roles of different spectra of UV radiation, behavior, age of exposure, and year of birth in producing skin cancers and other human health effects.

Finally, in their review of the first prospective study, the SAB raised a number of methodological, technical, and empirical issues for the 812 project team to consider. Many of these issues are related to the advancements in linkages between ODS emissions and ozone depletion; between ozone depletion and UV changes; and between UV changes and health effects. The SAB also recommended that the next 812 study provide an enhanced analysis of the uncertainty associated with Title VI benefits and costs.

To update the first prospective study's summary of stratospheric ozone protection costs and benefits – especially in light of the SAB's and others' comments and questions – we plan to make several revisions to the Title VI analysis methodology, primarily to the benefits assessment. The remainder of this appendix discusses this revised methodology First we describe the proposed ODS emissions scenarios for the analysis. Next, we provide an overview of the approaches to estimating costs and benefits for Title VI. Finally, we list the major comments on the previous Title VI analysis and describe how these comments are addressed in the second prospective study.

SCENARIOS

As in the rest of the 812 analysis, we propose to develop a pre-CAAA baseline scenario without CAAA-related ODS regulations and a post-CAAA scenario that includes Title VI ODS controls. The Clean Air Act Amendments ODS Title VI phase out scenario ("post-CAAA scenario") will reflect compliance by the United States and all of the rest of the world with the cumulative controls required under the major international agreements reached over the past fifteen years. These agreements include the original Montreal Protocol, the London Amendments, the Copenhagen Amendments, and the latest agreement, the Montreal Adjustments. All of these control programs except the Montreal Adjustments were reflected in the control scenario of the first prospective study. The increasing stringency of the ODS restrictions imposed by each of these policies is summarized in Exhibit E-1.

Exhibit E-1: ODS Restrictions Mandated by Four International Agreements

Policy/Emission Scenario	Description
Montreal Protocol (1987)	Developed countries subject to a freeze on CFCs in 1989, declining to a 50% cap in 1998; Freeze on halons in 1992. Developing countries subject to the same restrictions with a 10-year delay.
London Amendments (1990)	Developed countries subject to a phase out of CFCs, halons, and carbon tetrachloride by 2000, and methyl chloroform by 2005. Developing countries subject to the same restrictions with a 10-year delay.
Copenhagen Amendments (1992)	Developed countries subject to an accelerated phase out for CFCs (1996), halons (1994), carbon tetrachloride (1996), and methyl chloroform (1996); methyl bromide freeze in 1995, and HCFC controls beginning with a freeze in 1996, declining to a full phaseout in 2030.
Montreal Adjustments (1997)	Developed countries subject to all existing controls and a methyl bromide phase out by 2005. Developing countries subject to all existing controls, a freeze on HCFCs in 2016 with an eventual phaseout in 2040, and a methyl bromide freeze in 2002, declining to a full phaseout in 2015.

The second prospective analysis will measure all costs and benefits of Title VI provisions relative to a baseline Pre-CAAA scenario. Under the pre-CAAA scenario, the United States will be assumed to comply with ODS controls only for the original Montreal Protocol, which predates the Clean Air Act Amendments by several years. This means that the United States will only be subject to a freeze on CFCs in 1989, which then drops to an 80% cap in 1993, and to a final 50% cap in 1998. Halons will be subject only to a freeze in 1992. All other U.S. ODS uses will be uncontrolled for this scenario. Under the Post-CAAA scenario, the United States will also comply with the ODS phaseout controls as specified in Title VI, Sections 604-606. In addition, the Pre-CAAA scenario will assume that all countries other than the United States will comply with all of the restrictions embodied in the various international agreements up to and including the Montreal Adjustments. Thus, the rest of the world's emissions will be the same in the Pre-CAAA and the Post-CAAA scenarios. Exhibit E-2 presents a brief description of each scenario to be used in the analysis.

Exhibit E-2: Summary of Scenarios for the Title VI Cost/Benefit Analysis

Title VI Scenario Summary		
	Assumptions/Requirements	
	United States	All Other Countries
"Pre-CAAA" Baseline Scenario	No ODS controls beyond those mandated prior to the 1990 Clean Air Act Amendments (i.e., only the Montreal Protocol controls on CFCs and halons)	Full compliance with ODS reductions in accordance with the Montreal Protocol, the London Amendments, the Copenhagen Amendments, and the most recent Montreal Adjustments international agreements
"Post-CAAA" Control Scenario	Implementation of Sections 604-606 (ODS Phaseout) Implementation of Sections 608-609 (ODS product servicing, recycling and disposal) Implementation of Section 611 (ODS labeling)	Full compliance with ODS reductions in accordance with the Montreal Protocol, the London Amendments, the Copenhagen Amendments, and the most recent Montreal Adjustments international agreements

COST ESTIMATION APPROACH

The approach to estimating costs of Title VI provisions is essentially the same as the one used in the previous prospective analysis. Existing regulatory impact assessments (RIAs) for individual provisions of Title VI will be the source of social cost data for the phasing out of ODS. The total cost estimate of Title VI comprises the costs of Sections 604 and 606 and the incremental costs of sections 608, 609, and 611.

To update the cost analysis, EPA plans to retrieve original cost data from each RIA for use in the second prospective analysis. Costs are evaluated between 1990 and 2075, as in the first prospective. The proposed discount rate for the primary cost estimate is three percent, with a sensitivity analysis using a rate of seven percent.

BENEFITS ESTIMATION APPROACH

The Title VI benefits approach will provide estimates for human health and ecological effects based on a comparison of the baseline Pre-CAAA and Post-CAAA control scenarios. The primary difference between the benefits estimation approach in the first and second prospective analyses is that the second prospective will not rely on RIAs for health benefit estimates but instead will generate new estimates using EPA's Atmospheric Health Effects Framework (AHEF) model. This model consists of several modules that compute stratospheric ozone concentrations from past and predicted future emissions of ODS, forecast ground-level UV resulting from the predicted stratospheric ozone concentrations, and predict future health effects due to increased UV exposure. The AHEF is the centerpiece of the Title VI benefits analysis for the second prospective study.

To calculate monetary values of quantified Title VI benefits, EPA will multiply the physical effects estimates by appropriate unit values for each effect. EPA plans to re-evaluate and update, if necessary, the unit values used in the first prospective analysis. Monetized benefits for each effect category will be expressed as a net present value, using a discount rate for primary estimates of three percent. (A rate of seven percent will be used for a sensitivity analysis.) Total monetized Title VI benefits will be estimated by summing net present value benefits across effect categories.

In addition to the benefits estimated by AHEF, EPA will include in its analysis a qualitative discussion of health and ecological benefits that scientists have identified but that cannot yet be quantified. A search of the available literature reveals very little conclusive information regarding quantified health and ecological benefits from the reduction of future emissions of ODS. The available information does indicate that any currently unquantified health and ecological benefits are minimal compared to the benefits estimated by AHEF.

<u>AHEF Modeling Approach</u>

This section first summarizes the main steps associated with the AHEF modeling approach and describes the inputs for each step in the model approach. This is followed by an outline of the uncertainties associated with the AHEF model and its inputs and a discussion of the proposed changes to the model that are currently being developed by EPA.

Figure E-1 presents a flow diagram of the steps and inputs to the AHEF model.

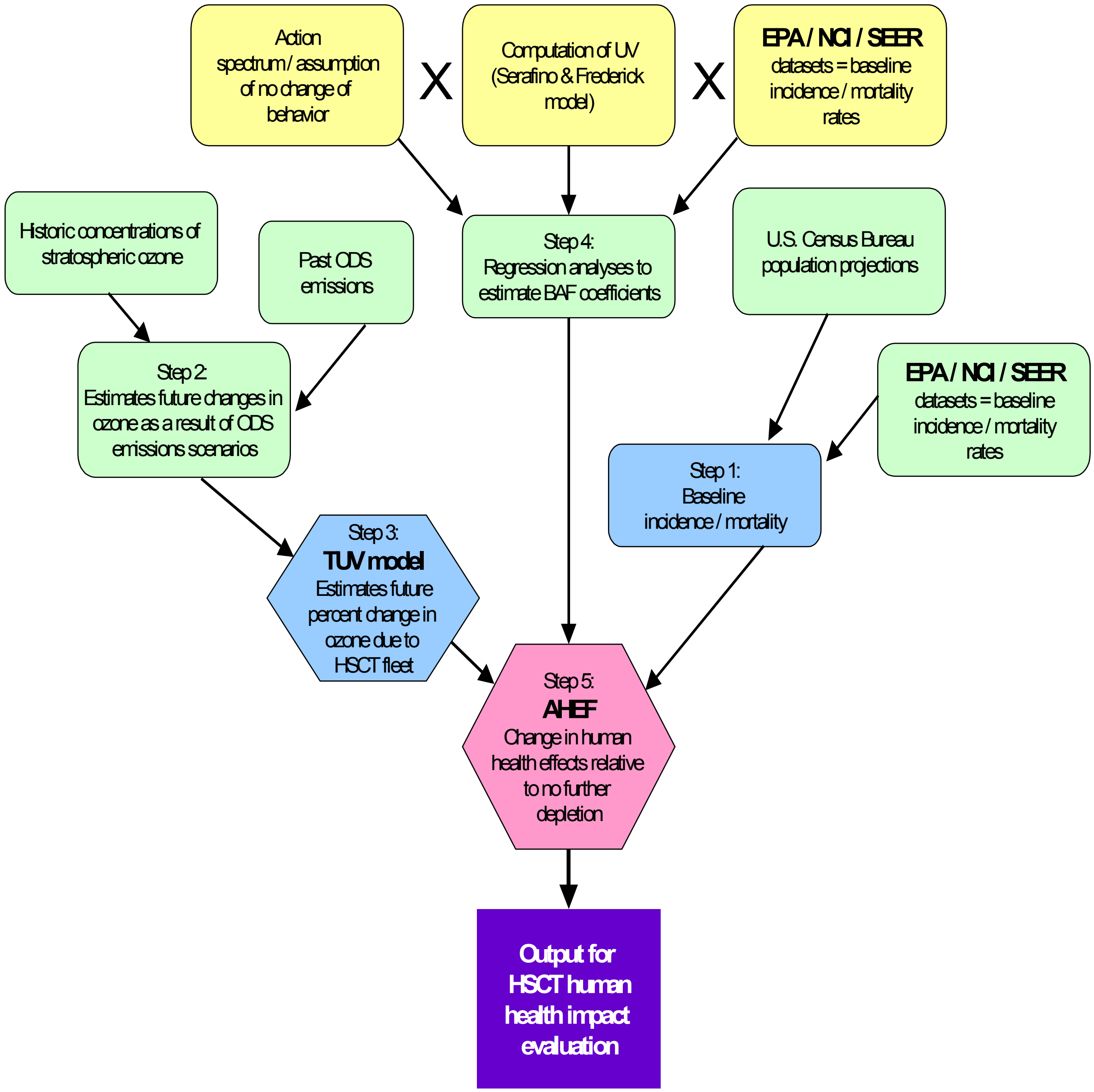

Figure E-1. Relationship between the models used for this evaluation of human health impacts. The symbols used in this diagram do not correspond to traditional flow chart notation. BAF = biological amplification factor. NCI = National Cancer Institute. SEER = Surveillance, Epidemiology, and End Results Program.

The AHEF has five main steps incorporated into the modeling approach. These steps lead to a prediction of incremental changes in incidence and mortality estimates for various UV-related health effects based on ODS emission scenarios. These steps are described below:

Step 1. Compute baseline projections of incidence and mortality assuming no further depletion of the ozone layer.

The AHEF defines an initial estimate of incidence and/or mortality for skin cancer and cataracts that would be expected to occur in the future if the concentration of stratospheric ozone were fixed at 1979-1980 levels (the first two-year period for which satellite measurements of stratospheric ozone exist). This is defined as the "no further depletion" scenario. Future skin cancer and cataracts incidence and skin cancer mortality that would have occurred in the absence of ozone depletion are assumed to be associated with these 1979-1980 ozone concentrations. Establishing these values provides a standard against which to evaluate changes in the mortality and/or incidence of these health effects resulting from future ODS emission scenarios (in the case of Title VI, the "Pre-CAAA" and "Post-CAAA" scenarios). The AHEF performs the following calculations to create initial estimates of incidence and mortality:

- Data on past cases of skin cancer and cataract incidence and mortality are used to derive rates for UV-related health effects in the US population. Rates are based on age, gender, and in some cases, birth year. The historical data was collected from the Surveillance, Epidemiology, and End Results Program (SEER) within the Cancer Control Research Program at the National Cancer Institute (NCI) (Ries *et al*, 1999). The ratio of SEER-based incidence to mortality is calculated and then applied to EPA/NCI mortality rates to generate comprehensive future incidence rates ((Scotto *et al*, 1991) and (Pitcher and Longstreth, 1991)).

- Future US population is estimated by age and gender groupings. Data are gathered from U.S. Census Bureau population projections.

- The number of people in each age and gender group is multiplied by the appropriate incidence and/or mortality rate to produce an estimated baseline number of future skin cancer and cataract cases per year.

Because skin cancer and cataract rates as well as ozone depletion vary across latitudes, the initial US health effects data are stratified into three latitude regions based on specific population estimates from U.S. Census Bureau. Furthermore, because skin cancer incidence and mortality among non-white populations is not well understood in terms of baseline rates of responsiveness to increased UV exposures, currently only white populations are examined in this framework. Once the required information becomes available, non-white populations will be integrated into the model; however, this is not expected to be accomplished within the timeframe of the second prospective analysis.

Step 2. Model the impacts of future emissions of ODS on stratospheric ozone concentrations.

Since 1978, satellites have been providing measurements of stratospheric ozone by latitudinal band. Data from the first of these satellites, the Nimbus 7, indicate that during the satellite's lifespan from 1978 to 1993, ozone measurements have declined in a manner that appears to be related to an increase in the concentration of stratospheric chlorine and bromine. This relationship enables the AHEF to use ODS emissions to predict decreases in stratospheric ozone. First, the model uses regression coefficients to quantify the relationship between past ODS emissions and past changes in ozone concentration, as follows:

- Measurements of historical concentrations of stratospheric ozone are obtained from satellite data.

- The amount and type of past emissions of ODS are combined with the information on each species' degree of dissociation and rate of transport to the stratosphere. Using this information, ODS emissions are expressed in terms of equivalent effective stratospheric chlorine, or EESC, for each year for which satellite-based ozone measurements are available.

- Statistical linear regressions are performed to obtain a measure of the correlation between ODS emissions expressed as EESC and satellite measurements of stratospheric ozone. These regressions are performed by month and by latitudinal band for each year.

To predict future changes in ozone as a result of different ODS emission scenarios (in this case for the "Pre-CAAA" and "Post-CAAA" scenarios), the AHEF converts the hypothesized emissions into EESC and multiplies by the regression coefficients obtained above to estimate future ozone depletion by month and latitude.

Step 3. Estimate changes in ground-level UV based on ozone depletion projections.

After future ozone concentrations have been estimated for a given ODS emissions scenario, future ground-level UV intensities can be calculated. The AHEF uses the results of the Tropospheric Ultraviolet-Visible (TUV) model to predict UV irradiance at ground level (Madronich 1992, 1993b; Madronich and de Gruijl 1993; Madronich *et al.* 1996, 1998). TUV estimates surface UV levels based on total column ozone at different latitudes, the solar zenith angle, the relative weights placed on different portions of the UV spectrum, and other atmospheric characteristics. Thus, the modeling framework can use projected ozone concentrations to calculate the UV dose at any given location and for any given time period (e.g., peak intensity day of the year or the sum of exposures incurred over the entire year). Several studies that test the accuracy of TUV against direct measurements of surface UV levels have been completed (e.g., Shetter *et al.* 1992, 1996; Kirk *et al.* 1994; Lantz *et al.* 1996).

The TUV estimate of the spectral UV irradiance, $F(\lambda, x, t)$, at time t, location x, and wavelength λ, may be represented as the product of the solar spectral irradiance at the top of the atmosphere, $F_{toa}(\lambda)$, and an atmospheric transmission factor, T.

$$F(\lambda, x, t) = F_{toa}(\lambda)\ T(\lambda, x, t; \Theta_0, O_3, \text{clouds, aerosols, } \ldots) \qquad \text{Equation E-1}$$

$F_{toa}(\lambda)$ is based on direct measures of the sun by satellite, balloon, and ground-based instruments. The value of T is impacted by a variety of factors including the solar zenith angle (Θ_0), the earth-sun distance, and a number of atmospheric optical properties (e.g. absorption by ozone, pollutant gases, scattering by air molecules). The calculation may also optionally include values for atmospheric particles such as clouds and aerosols that can affect absorption and scattering. Finally, TUV includes surface reflections, as they can contribute to the radiation incident at the surface (see for example McKenzie *et al.* 1998).

TUV then uses vertical profiles of air density, temperature, and ozone from the United States Standard Atmosphere to calculate the transmission factor (T). The spectral irradiance at any location and time, F(l, x, t), is then calculated by solving for radiative transfer within uniform layers of the atmosphere using an accurate numerical scheme, the discrete ordinates method developed by Stamnes *et al.* (1998) and modified by Madronich *et al.* (1999).

Step 4. Derive dose-response relationships for the incidence and mortality of skin cancer and cataracts from primary data or are obtained from the most up-to-date literature.

When estimating dose-response relationships for human health effects and UV exposure, controversy exists regarding which portion of the spectrum of UV radiation is the best measure of the "dose" an individual receives from the sun. This decision is critical because ozone depletion primarily alters the amount of biologically active UV-B radiation that reaches the ground, leaving the less harmful UV-A portion of the spectrum largely unchanged. In the attempt to quantify this "dose," scientists have created mathematical expressions describing the amount of UV-B and UV-A wavelength radiation that may cause health effects in mice and fish (e.g., DNA damage, skin cancer, and cataract). Based on these studies, a number of different "action spectra," as these weighting schemes are called, have been proposed as predictors of the dose of UV radiation needed to induce skin cancer and cataracts in humans.

Once a particular action spectrum for a human health effect is selected, the second component in developing dose-response relationships for UV exposure requires determination of the degree to which incidence of skin cancer and cataract increases with more intense UV exposure. These dose-response relationships, known as biological amplification factors (BAFs), are usually estimated for cutaneous malignant melanoma (CMM); for the two non-melanoma skin cancers (NMSC), basal cell carcinoma (BCC) and squamous cell carcinoma (SCC); and for cataracts based on actual human incidence and mortality data. Information on skin cancer incidence and mortality rates among populations at different latitudes is combined with the difference in the intensity of UV exposure across those latitudes (e.g., southern latitudes are exposed to higher levels of UV radiation than northern locations) to estimate BAFs. This latitude gradient can also be used to estimate the way in which skin cancer and cataract incidence and/or mortality will change over time as ozone depletion occurs and UV doses at all latitudes rise.

The current peer-reviewed version of the AHEF uses two action spectra in its estimates of dose-response relationships for UV exposure (U.S. EPA, 2001). The SCUP-h[1] action spectrum is used to predict the dose of UV exposure needed to induce melanoma incidence and mortality as well as NMSC incidence and mortality (de Gruijl *et al.* 1993). The DNA-h action spectrum is used to predict the dose of UV exposure needed to induce cataract incidence (Setlow, 1993). In addition, data on the baseline incidence and mortality rates for human health endpoints are found in EPA, NCI, and/or SEER datasets.

Step 5. Combine the above inputs to project future levels of skin cancer and cataract incidence and skin cancer mortality.

The final step in the modeling framework incorporates the previously discussed inputs to project future incremental skin cancers and cataracts generated under a particular emissions scenario as compared to the no-further-depletion scenario. For all scenarios, the base case relative to which incremental health effects are computed is the future skin cancers and cataracts that would have occurred in the absence of ozone depletion from the 1979-1980 concentrations. Declines in future health effects due to tightening ODS emissions reduction targets are then calculated as the difference between the Pre-CAAA and Post-CAAA scenarios. Benefits will be calculated over the period of 1990 to 2165, to reflect the long time period during which stratospheric ozone depletion occurs and the health effects become manifest in the population.

The final step begins when the model calculates the future annual percentage change in UV dose for a given action spectrum across the three latitudinal bands of interest. Multiplying the percentage change in UV exposure in a future year by the appropriate BAF (both specific to a given UV action spectrum) yields the percentage change in future skin cancer incidence and mortality as well as cataract incidence attributable to the future change in ozone concentrations. These percentages are then multiplied by the "no further depletion" incidence and/or mortality for that health effect to obtain the incremental changes in incidence and/or mortality for a particular ODS emission scenario relative to no further ozone depletion.

[1] SCUP-h = Skin Cancer Utrecht Philadelphia action spectrum, adjusted for human skin transmission.

Future updates to the AHEF model

EPA is currently preparing a new version of the AHEF model set for peer review by the end of the current (2003) fiscal year. This version of the model is expected to include the following improvements:

- *The addition of newly developed action spectrum for cataracts by Oriowo et al. (2001).*

- *A CMM weighting scheme for early age exposure.* As discussed above, development of melanoma is more closely associated with UV exposure during childhood than with cumulative UV exposure. In the new version of AHEF the results for CMM mortality using annual and peak day exposures are computed either by weighting all exposures equally over a person's lifetime, or by weighting only the exposures received between age one and age 20. More specifically, the following approach was used for estimating whole life versus early life exposures:
    - *For whole life esposure:* exposures throughtout the individual's lifetime are given equal weighting (i.e., each year's exposure is counted in the results).
    - *For early life exposure:* only exposures received between the ags of one and 20 are considered (i.e., later life exposures do not contribute to the results).

The peer review process for the version of the AHEF model including these improvements is expected to be completed in time to use the newer version of the model in estimating Title VI benefits for the second prospective study.

Uncertainties associated with the AHEF model

There are several important uncertainties associated with the AHEF model. This section describes these uncertainties and, where possible, an estimate of the potential magnitude and expected direction of possible bias. Exhibit E-3 presents a summary of these key uncertainties and their expected effect on the AHEF model estimates.

Exhibit E-3: Factors Contributing to Uncertainty

Factor	Parameter	Bias of Current Estimate
Change in UV Estimates	Atmospheric parameters assumption	unknown
	Long-term Systematic Changes in Atmospheric Opacity (e.g. clouds, aerosols, other pollutants)	unknown
Changes in Health Effect Estimates	Action Spectrum Choice	unknown
	Action Spectrum Derivation	unknown
	Future Population Composition and Size	unknown
	Latency	overestimate
	Changes in Human UV Exposure Behavior	unknown
	Improvements in Medical Care/Increased Longevity	overestimate

There is a small amount of uncertainty introduced in the TUV model (Step 3). The uncertainty stems from the assumption that relative to the specific change in ozone all other factors (air pollution, cloud cover, etc.) remain constant. The direction of the bias created by this uncertainty is unknown, however it is expected to be a small effect compared to other uncertainties associated with the AHEF methodology.

The composition of the future atmosphere is unknown. Impacts from ODS phaseout scenarios as well as future climate changes could result in increases in atmospheric water vapor and cloud cover. In addition the impact of global warming on future atmospheric composition is unknown. These factors introduce an unknown factor of uncertainty into the model estimates of cataract incidence and skin cancer incidence and/or mortality.

A degree of uncertainty is present in the estimates of the dose-response relationships or BAFs. This uncertainty stems from the assumption that the SCUP-h action spectrum is an adequate predictor of NMSC in addition to the CMM for which it was developed. The BAFs developed for SCC and BCC using SCUP-h are estimated at 2.5 +/- 0.7 and 1.4 +/- 0.4 respectively (de Gruijl *et al.* 1993, Longstreth *et al.* 1998). The degree of uncertainty associated with these BAF estimates may also be expressed as a range of approximately 30 percent.

An additional factor of uncertainty is associated with the action spectra, stemming from the laboratory techniques and instrumentation used for their derivation. The potential for inconsistencies between the wavelengths of UV received by the subject and the intended wavelengths can affect the measured result, sometimes by orders of magnitude. While the potential for a large uncertainty is present, we cannot predict in what direction the bias would occur, as the wavelengths received could be greater or less than those measured. Also, the action spectra are estimated using monochromatic light sources, which are not fully representative of the polychromatic light received directly from the sun.

Steps 1 and 4 of the model incorporate future population predictions from the U.S. Census Bureau. AHEF uses estimates of population grouped by race, gender, age, and location. The Census

Bureau does present an uncertainty factor of +/- 0.1% for its overall population estimates, however a similar estimate of uncertainty is not predicted for the population groups used in AHEF. There is a possibility that the uncertainty factors for each of these groups could be more or less than the overall estimate, therefore it is not useful to apply the overall factor to the population groupings used in the AHEF model.

In the case of the AHEF model, latency refers to the lag time between UV exposure and the manifestation of a given health effect. Both skin cancer latency and early life exposure have been identified as potential risk factors associated with increased susceptibility to CMM. Skin cancer latency is a potential risk factor because the manifestation of skin cancer may not appear for a length of time, during which a person may continue practices that expose the skin to harmful UV. However, the current peer-reviewed version of the AHEF does not model lag time due to difficulties caused by the limited state of knowledge about latency and its mechanisms prevailing at the time of the peer review (Madronich, 1999). Therefore, a quantitative estimate of this source of uncertainty is unavailable. If there is a significant lag and it is not included in the model, then benefits are likely overestimates since the benefit stream has not been properly discounted.

In the case of the proposed weighting scheme for early age exposure, there is uncertainty associated with the timing of the incremental effects and who will bear them. More specifically, for the cumulative lifetime exposure assumption, the risks of ozone depletion are borne primarily by the present population of adults who will experience these health effects as they age. It is children and future generations who will experience increased early life UV exposures and the associated incremental health effects later in their lives. It should be noted that this shift of health risks does not reflect a formal modeling of CMM latency, which would involve an elaborate method for assigning different weights to exposures incurred at different ages or some other yet-to-be-developed approach.

There are a number of factors that may have an additional, unknown effect on future incidence and/or mortality rates for skin cancer and cataracts. These include future population composition and size, future UV exposure behavior, improvements in medical care and predictions of increased longevity. The expected increase in Hispanic populations could lead to a decrease in incidence and mortality rates due to the higher pigmentation found in these populations. The bias of future UV exposure is more difficult to predict and innovations and increased awareness could lead to decreased exposure to UV, however an increased sense of protection could lead to longer periods of exposure, thus negating the positive effects of sunglasses and sunscreens.

However, most of these confounding factors are assumed to be constant in the AHEF model. Therefore sunbathing frequency and attire, the use of sunscreens and sunglasses, the detection and treatment capacities of the medical system, and other conditions are assumed to remain unchanged in the future. The health effects modeling does account for the gradual shift from outdoor work earlier in the last century to factory and office occupations through the 1950s, and it does take into account the evolving demographics of the United States over time. It remains true that significant changes in UV-related behavior patterns could generate outcomes different from those predicted by the existing model.

Benchmarking the results of a model against available observed data can help to predict the accuracy of the model as well as determine the direction of potential biases. The majority of inputs to the AHEF model are derived statistically using real data (e.g., EESC to ozone, BAFs), therefore calibration is not an issue. The results of the model, however, have yet to be benchmarked against observed data. Several activities can be undertaken to assess actual column ozone measurements compared to AHEF predictions, though all will require substantial time and monetary commitments. First, the AHEF output of column ozone concentrations (in Dobson units) by year and latitudinal band can be compared to observed data, as available by region. Second, ground level UV monitoring can be obtained and assessed to help improve modeling estimates, particularly in urban areas. It should be noted that the AHEF model and all of its individual inputs have been peer-reviewed.

MAJOR COMMENTS ON STRATOSPHERIC OZONE ANALYSIS FROM FIRST PROSPECTIVE STUDY

This section lists the major comments from SAB and others on the Title VI analysis performed for the first prospective and discusses how the approach to Title VI benefits and costs for the second prospective will address these issues.

1. Incorporate tropospheric ozone concentration reductions expected under other regulations as negative benefits.

The great majority of shielding provided by the ground level ozone against the harmful effects of UV-b radiation results from naturally occurring ozone in the stratosphere, but the 10 percent of total "column"ozone present in the troposphere also contributes (NAS, 1991). A variable portion of this tropospheric fraction of UV-B shielding is derived from ground level or "smog" ozone related to anthropogenic air pollution. Therefore, strategies that reduce ground level ozone could, in some small measure, increase exposure to UV-B from the sun.

While EPA's analyses demonstrate it is possible to provide quantitative estimates of benefits associated with globally based strategies to restore the far larger and more spatially uniform stratospheric ozone layer, the changes in UV-B exposures associated with ground level ozone reduction strategies are much more complicated and uncertain. Smog ozone strategies, such as mobile source controls, are focused on decreasing peak ground level ozone concentrations, and it is reasonable to conclude that they produce a far more complex and heterogeneous spatial and temporal pattern of ozone concentration and UV-B exposure changes than do stratospheric ozone protection programs. In addition, the changes in long-term total column ozone concentrations are far smaller from ground-level programs. To properly estimate the change in exposure and impacts, it would be necessary to match the spatial and temporal distribution of the changes in ground-level ozone to the spatial and temporal distribution of exposure to ground level ozone and sunlight. More importantly, it is long-term exposure to UV-B that is associated with effects. Intermittent, short-term, and relatively small changes in ground-level ozone and UV-B are not likely to measurably change long-term risks of these adverse effects.

For all of these reasons, EPA believes we will continue to be unable to provide reliable estimates of the changes in UV-B shielding associated with ground-level ozone changes. This inability lends an upward bias to the net monetized benefits of tropospheric ozone reduction that will be presented in second prospective criteria pollutant analysis. It is likely that the adverse health effects associated with increases in UV-B exposure from decreased tropospheric ozone would, however, be relatively very small from a public health perspective because 1) the expected long-term ozone change resulting from the CAAA is likely to be small in comparison to the sum of total column natural stratospheric and tropospheric ozone; 2) air quality management strategies are focused on decreasing peak ozone concentrations and thus may change exposures over limited areas for limited times; 3) people often receive peak exposures to UV-B in coastal areas where sea or lake breezes reduce ground level pollution concentrations regardless of strategy; and 4) ozone concentration changes are greatest in urban areas and areas immediately downwind of urban areas, where people are more likely to spend most of their time indoors or in the shade of buildings, trees or vehicles.

EPA has also explored this issue recently through collaboration with Dr. Sasha Madronich of the National Center for Atmospheric Research. His methods and data, while somewhat preliminary in nature, result in predictions of health effects from tropospheric ozone decreases that are far lower than those cited by the SAB. In brief, his modeling accounts more realistically for the geographical areas and the seasons in which people receive their UV exposures. These are then compared to realistic estimates of where and when tropospheric ozone depletion might occur. His analysis is thus more credible than others in which tropospheric ozone depletion is assumed to be distributed evenly across the entire nation.

2. Examine the uncertainties in the cost and benefit estimates.

In a recent project that is nearing completion, EPA explored the many sources of uncertainty concerning the health effects predicted by the AHEF. This study was conducted by EPA for NASA's hypersonic commercial transport (HSCT) project. It was extensively peer reviewed by leading atmospheric researchers (U.S. EPA, 2001).

The major sources of uncertainty in the AHEF examined in the HSCT analysis include the following:

- computing projected future stratospheric ozone concentrations from projected EESC,
- calculating ground-level UV based on projected stratospheric ozone concentrations,

- using alternative action spectrum weighting schemes for human health effects, and

- computing health effects using specific action spectra, incremental UV exposure, and the associated BAFs.

The HSCT analysis generated distributions for some pieces of the model (e.g., BAFs and atmospheric regression coefficients) and plus/minus factors for other parts (e.g., stratospheric ozone to ground UV estimation factors). EPA is investigating whether the analyses in the HSCT study can be applied to the AHEF results to be used in the revised 812 study.

3. Include the costs and benefits of new ozone-protection regulations.

The revised 812 study will incorporate current (and anticipated future) stratospheric protection rules, such as the methyl bromide freeze and eventual ban. EPA has developed several RIAs in the past few years that provide a source of cost estimates for rules not included in the first prospective. In addition, emission reductions associated with these rules will be incorporated into the control scenario for the benefits analysis.

4. Standardize the Value of a Statistical Life (VSL) for human health benefits and discounting for costs and benefits.

EPA plans to employ the same VSL estimate used for all mortality benefits from all CAA Titles, including Title VI. We also propose performing a sensitivity test that considers the age distribution of avoided skin cancer mortality and a distribution of VSL by age cohort to generate monetized benefits estimates for avoided mortality.

Adjusting the discount rate for the costs of the various stratospheric ozone protection rules to conform to the three percent discount rate for the primary analysis may be difficult unless the underlying original output information can be retrieved. For recent regulations, these data are expected to be available. For older rules with limited data on components of the benefit and cost streams, EPA will investigate the merits of applying adjustment factors.

5. Revisit Non-Melanoma Skin Cancer (NMSC) Mortality Estimates

Actual data on NMSC mortality have been incorporated in the revised AHEF over the past several years – including baseline incidence by age and gender, and estimated BAFs. This information was not available for the first prospective analysis. The result of using these data is that NMSC mortality is about 60% lower than the original 1% of incidence assumption. Hence, the new version of the AHEF will be used to address this issue.

6. Examine possible noncompliance with projected ODS-controls by other nations.

EPA and ICF recently evaluated a limited number of scenarios involving non-compliance of developing countries with future ODS restrictions to explore the impact of non-compliance on U.S. citizens. The empirical results of these and other simulations will be evaluated for possible incorporation in the second prospective study.

7. Directly measure social costs of ODS controls instead of using ex ante estimates.

As explained in the Appendix G of the first prospective study, EPA presents estimates for Title VI as net present values of the strams of annual costs and benefits due to the long-term nature of the mechanisms of stratospheric ozone depletion and measures taken to avoid depletion. For EPA as a whole, systematic ex post cost or benefits measurement/survey efforts have rarely been undertaken except for very broad categories of costs of pollution control. In EPA's *Cost of Clean* report, the primary source of information was the Census Bureau's MA200 survey of industry pollution control costs. Because these data were so aggregated and because imputing costs to EPA's regulations vs. other regulatory authorities, much less to voluntary expenditures, was not possible, this report and its underlying data are not suitable for estimating the on-going costs of EPA's stratospheric ozone protection efforts.

8. Review the discussion of the interaction between stratospheric ozone recovery and global climate change.

EPA's original calculations of stratospheric chlorine and bromine concentrations associated with changes in emissions incorporated the ability of CFCs, halons, and other ozone depleting chemicals to act as greenhouse gases. The atmospheric chemistry model adjusts column ozone and temperature so that they are consistent with consensus ozone-depleting potential and global warming potential estimates. The model also reflects radiative and chemical feedback from water vapor, ocean absorption, atmospheric circulation effects, and chemical interactions between substances. Some more recent studies have suggested that climate change could have a significant impact on the recovery of stratospheric ozone, beyond what was accounted for in original modeling work. It has been hypothesized, for example, that increased temperatures caused by climate forcing of greenhouse gases and aerosols could cool the stratosphere, thus increasing the time it takes for ozone to recover. At this point, however, little is known about the degree to which climate change may affect stratospheric ozone recovery and conversely, any relationship that may exist between stratospheric ozone recovery and climate change. Unless improved three-dimensional models of atmospheric chemistry and climate processes are developed in a sufficiently timely and rigorous manner, the second prospective study will not attempt to further assess the potential effects of climate change on ozone under alternative scenarios.

9. Update the human health benefits of stratospheric ozone recovery to reflect changes during the last decade in the sciences concerning ODS emissions and ozone depletion/recovery, ozone-to-UV exposures at the ground, and the complex relationship between human UV exposures (duration, action spectrum, latency, and so forth) and skin cancer and cataracts.

As outlined in the previous section, the revised AHEF uses the most up-to-date atmospherics inputs for a 1D model, a revised methyl bromide "alpha factor" of 55 (instead of 40), and a new statistically-estimated set of stratospheric atmospheric EESC-to-ozone depletion parameters. The column ozone-to-UV on the ground model is current (Dr. Madronich's TUV), and various new health effect action spectra and exposure assumptions have all been explored and incorporated into the AHEF. EPA plans to address these issues by re-running the various policy scenarios of interest using the revised AHEF. This is also necessary because recent stratospheric ozone protection rules' benefits have all been estimated using the new modeling framework.

With respect to modeling latency, although the epidemiological literature strongly suggests this may be appropriate, especially for cutaneous malignant melanoma, there is no widely accepted methodology that directly incorporates latency. The approach adopted in the AHEF is normally to assume that it is cumulative lifetime exposure that results in skin cancers of all types. The AHEF can use cumulative peak day exposures instead and it can weight exposures received at different ages unequally. The latter does shift the incremental health effects farther into the future and shifts the bulk of these health effects from individuals living today to future generations, thus roughly simulating a latency relationship. EPA plans to inviestigate the merits of this approximation approach for use in the second prospective study, and seeks the advice of the Council regarding its potential utility and technical merit.

Finally, the incorporation of advances in detection and treatment of skin cancers in recent years would be a very useful task to undertake. Unfortunately, this would require a substantial amount of new data collection and analysis, and the results would probably be difficult to integrate into the current framework of inter-related health effects inputs to the AHEF. The AHEF necessarily relies on historical data to calculate baseline and incremental health effects from UV exposure, so attempting an approximate adjustment based on more recent, and arguably non-comprehensive, information would likely add to the uncertainties of the results rather than reduce them. EPA seeks the advice of the Council regarding this issue.

10. Do the reported Title VI Costs and Benefits Represent World-Wide or U.S.-Specific Costs and Benefits?

The benefits and costs reported in all of the RIAs and related analyses are for the United States only. This analytical scope is consistent with the rest of the second prospective study.

11. Different timeframes for costs and benefits.

The results for stratospheric ozone protection included in the first prospective study reported costs through 2075. In order to capture all of the health benefits of ODS controls between 1985 and 2075, the benefits model must track anyone in the United States who experiences ozone depletion and increased UV up through 2075 until their deaths. Thus, in the extreme, this is 90 years after 2075. Clearly, the incremental incidence and mortality decline as the years get more distant from 2075 because fewer and fewer people are alive who experienced decrease UV up to 2075 relative to depletion. They nevertheless remain beneficiaries of ozone recovery effects prior to 2076 as long as they were alive during those years.

12. Sensitivity of 1D atmospheric modeling to geography and season.

Using a 1D atmospheric modeling framework does not imply that the outputs are insensitive to latitude and month of the year. While it does assume that the EESC is the same world-wide, the statistically-estimated parameters that translate EESC (based on ODS emissions and other factors) into stratospheric ozone concentration estimates are latitude- and month-specific because they were estimated using latitude- and month-specific ozone measurements. Thus, the column ozone estimates are sensitive to latitude and time of year.

Furthermore, the TUV model – which is used for predicting ground-level UV intensities by location and time – is similarly sensitive to latitude and time (indeed, to the hour of the day). Thus, UV intensities at different latitudes are very different due to the angle of the sun and amount of the atmosphere through which the sun's rays travel.

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